TRIPLETT

INSTRUCTION MANUAL

# MODEL 3490

## TRANSISTOR ANALYZER

PRICE $1.00

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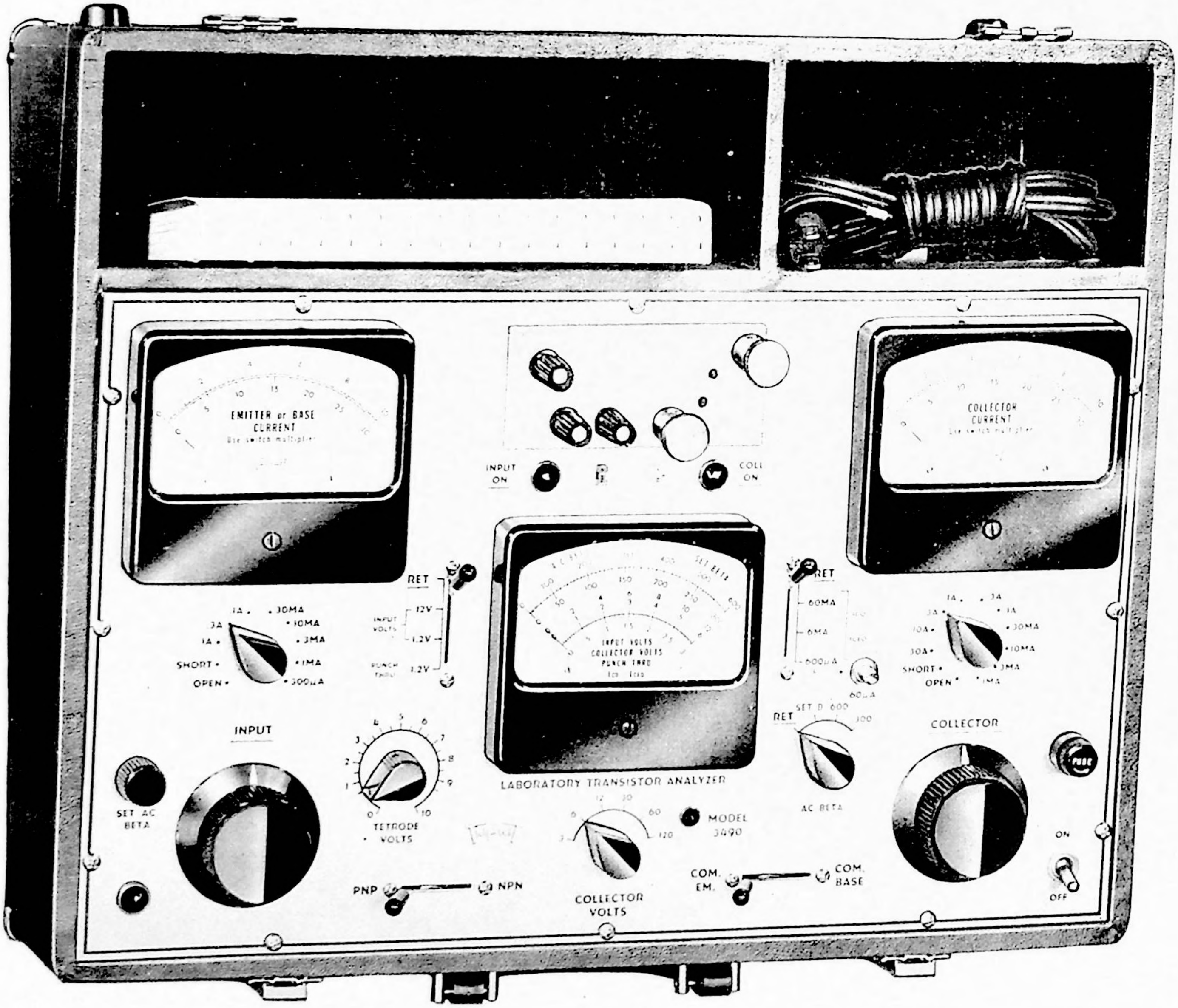
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Model 3490

# TRIPLETT TRANSISTOR ANALYZER

### MODEL 3490

This Transistor Analyzer is designed for maximum flexibility, wide coverage of both signal and power transistors, and standard readings of all measurement values in volts, amperes and ohms as listed by the semi-conductor manufacturers. Continuous current and continuous voltage controls are a built in feature, with large accurate meters to read static as well as dynamic values. Interlocked switching circuits with warning light indicators protect the semi-conductors from voltage transients, while at the same time assisting the operator in the testing procedure. Collector Current and Emitter or Base Current is monitored all the time, and the controls with other instrumentation provide facilities for plotting complete characteristic curves as well as taking single readings.

## TECHNICAL DESCRIPTION

### THE METERS AND RANGE SELECTORS:

Transistors are inherently current sensitive devices as compared to vacuum tubes which are primarily voltage sensitive. Current readings and current amplification values are therefore, the important guiding factors in transistor evaluation. It is of utmost importance to know the Collector Current at all times, regardless of the parameter under measurement. This Transistor Analyzer is equipped with a four and one half inch multirange ammeter which reads continuously the Collector Current on any one of 10 overlapping ranges. This meter is located in the upper right hand corner of the panel. The scale captioned "Collector Current" has two arcs; the outside one calibrated from zero to thirty, and the inside one from zero to ten. All of the current ranges are on a zero-ten and zero-thirty basis, from 1 milliampere to 30 amperes, and therefore, on any range **it is necessary only to add zero's** to the scale reading, or divide by ten to determine the exact Collector Current. It must be noted, that although the high ampere range is 30 amperes, the maximum usable current on this range is 15 amperes, limited to a maximum of 30 seconds at any one time. The Collector Current range selector switch is mounted directly below the Collector Current meter providing in combination an effective and accurate milliammeter and ammeter accurate to ±2%. In addition to the current ranges, this switch can be set to the "Open" and "Short" positions, which are used when taking emitter readings under conditions where the collector must be open or short circuited to the base.

Since this Transistor Analyzer has been designed to measure three or four terminal units in either the Common Base or Common Emitter configuration, the Input Current can be introduced or applied thru either the Emitter or Base. Accordingly, this meter is labeled "Input Current", and is mounted in the upper left hand corner of the panel. It reads Emitter Current when the Common Emitter-Common Base lever switch is in the Common Base position, and when the switch is indexed to the Common Emitter position, the Input meter reads Base Current. It was stated before and is repeated here that transistors are current amplifying devices, and therefore, this meter is connected to read Input Current **all the time.** Like the Collector Current meter, the Input Current meter has the same two arcs numbered zero to thirty. Continuous coverage is available from 300 to ten and zero to thirty. Continuous coverage is available from 300 microamperes full scale to 1 ampere full scale, accurate to ±2%. Again it is necessary only to add zero's or divide by ten to obtain the exact emitter or base current applied to the transistor. Also, the Input Current range selector switch is mounted directly below the Input meter for operational convenience. In addition to the current ranges, this switch can also be set to "Open" and "Short" positions, which are used when taking collector readings under conditions where either the emitter or the base must be open or short circuited to the collector circuit. It was stated before that the Collector meter reads Collector Current at all times, and that the Input meter reads Input Current all of the time. Therefore, the operator of the Transistor Analyzer has in front of him the two most important functional values on continuous display. Thus, by comparing the Input or Emitter Current and the Collector Current in the Common Base configuration, the value of alpha or forward current transfer ratio $h_{FB}$ can be determined. By comparing the ratio between Collector Current and the Input or Base Current in the Common Emitter configuration, the value of d-c Beta or forward current transfer ratio $h_{FE}$ is determined.

The third meter in the approximate center of the panel reads Collector Voltage all the time unless it is being used for some special function, such as a-c Beta, $I_{CO}$, $I_{CEO}$, Input Voltage or Punch Thru. Six voltage ranges with about a 2-1 ratio are calibrated on the black or d-c arcs figured zero to 3, zero to 6, and zero to 12. For the 30, 60, and 120 volt ranges it is again necessary only to add a zero to the meter reading. These voltage ranges are available by using the Collector Volts range selector switch directly below the meter. The combination of the range switch and the Collector Volts meter gives the operator continuous control of the Collector voltage through 120 volts accurate to ±2%. The use of the three meters presents to the operator a completely flexible operational analysis of the transistor under test. Collector Current can be plotted as a function of Base Current by holding the Collector Voltage constant—Collector Current can be plotted against Collector Voltage—Saturation Voltage or resistance can be measured, etc.

The scale arcs figured in red on this meter are calibrated for the a-c Beta or $h_{fe}$ readings, and are used for this measurement on low power or signal transistor types. The range of a-c Beta is determined by the position of the a-c Beta rotary switch which is located at the lower right of this meter.

### THE MAIN CONTROLS:

The main controls are set up on the panel to enable the operator to most conveniently explore the transistor characteristics and/or plot characteristic curves. There

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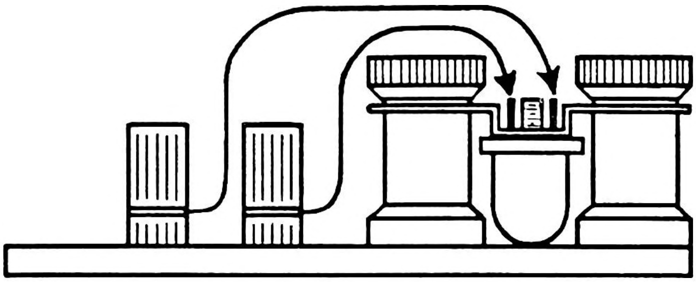
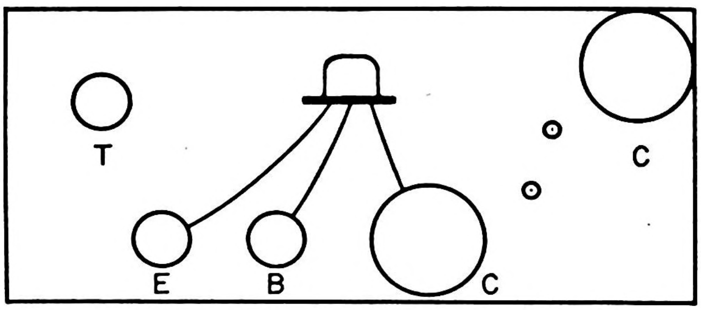


Where other types may be involved one of these combinations should provide sufficient thermal conductivity for any of the power types. If required, an external fitting may be used with leads fastened to the binding posts. A compartment is provided for such a device to the left rear of the connector block in the case.

On the signal types with long leads, it often saves time to connect the leads directly to the binding posts rather than insert them into the small sockets.




Where a transistor is equipped with a ground lead, this may be connected to the emitter post. On double base or tetrode units, the b2 terminal is connected to the red binding post. An example of this type is the 3N36.

THE HEAT SINK:

The solid slab of copper on which the binding posts are mounted forms with the two collector posts a substantial heat sink. This copper slab is insulated from the panel but is directly connected to the collector circuit. As mentioned under "Connections to Transistors", the copper and the brass nickel plated posts form the connection means to the power or signal transistors, aside from the 2 small sockets. When making connections to base, emitter or tetrode posts with bare leads, the operator should check to be sure these leads are spaced from the heat sink bar for insulation.

Buried in the copper on the under side is a socket for power transistors similar to the 2N457. Such transistors fit flush on the copper slab with the emitter and base wires on pins inserted in the two small holes marked "E" and "B" between the collector posts. Clamps fit under these two posts to hold the unit tight against the copper. Refer to the section entitled "Connections to Transistors".

THE INTERLOCKS:

To avoid overloads to transistors, instruments and analyzer components, circuit and switching interlocks are included in this device. On each position of the Input Switch, the impedance of the input supply is changed to provide as far as practical a constant current input supply regardless of emitter or base resistance. When the "Input Volts" lever switch is indexed to the "Punch Thru" position, the input (emitter) circuit is automatically opened regardless of the position of the Input Current switch. When the "$I_{co}$" lever switch is moved from its "RET" or Return position, the input circuit is automatically opened, regardless of the position of the Collector switch, thus affording instant entry of the sensitive $I_{co}$ meter into the Collector circuit without any possibility of overload, even if the transistor under test had just previously been operating at 15 amperes collector current. The switching sequence is such that the emitter or base circuit is opened before the microammeter is connected into the collector circuit. Conversely, the microammeter is removed from the collector circuit **before** the input supply is connected restoring full collector current thru the collector ammeter when this switch is returned to the RET position.

THE WARNING LIGHTS:

Switching transients of very short duration can damage or destroy transistors, a condition not usual with vacuum tubes. Protective circuits have been designed into this analyzer to prevent such damaging conditions, with indicators in the form of warning lights for operator observation. Directly under the emitter binding post on the panel is a red light, which comes on when any potential appears from the input supply. This light is extinguished when the Input control is turned to the off or extreme counter clockwise position.

Under the collector posts is a second red light. This is illuminated when the Collector circuit is energized. This light is extinguished when the collector variac is turned to the off or extreme counter clockwise position. These two indicators are very important to the operation of the Analyzer. Whenever connections are changed at the transistor terminals or whenever the configuration switch and the PNP-NPN switch are touched, the lights should be out. Also, when changing current ranges on either Input or Collector switches it is advisable to have the lamps extinguished. This procedure protects the transistor at all times. The operator should get in the habit of returning both controls to the off position, and "running up from zero" watching the three meters.

PRECAUTION: DO NOT HANDLE CONNECTIONS OR INSERT OR REMOVE TRANSISTORS OR DIODES FROM SOCKETS WHEN LIGHTS ARE ON.

The third red warning light is of a smaller size. It is located to the upper right of the "Collector Volts" switch. This is connected to an interlock circuit between the Collector Current and Collector voltage switch. When the current switch is indexed to any current range **over** 300 milliamperes, and at the same time the collector voltage switch is indexed to any potential range from 30 to 120 volts, this light will be illuminated. For example, to assume the current switch is indexed to the 10 ampere position, and the collector voltage switch to the 60 volts position, this power requirement of .6 kilowatts would overload the collector transformer and variac. The 10 ampere collector current can just as well be supplied on the 3, 6, or 12 volt range without such a high power requirement. By changing the "Collector Volts" switch to one of these lower voltage positions, the light will be extinguished. If on the other hand, a higher potential is required, the "Collector Volts" switch may be left in the 30, 60 or 120 volt position and the Collector Current switch indexed to the 100 ma, 30 ma, 10 ma or lower current position, where also the warning light will go out.

PRECAUTION: DO NOT PROCEED WITH TRANSISTOR OR DIODE MEASUREMENTS WHEN THIS LIGHT GLOWS RED.

# MEASUREMENT OR TEST PROCEDURE

INFORMATION:

Locate the type number of the transistor in one of the data books available from manufacturers. For transistors note the characteristic, PNP or NPN. Set the lever switch accordingly.

Find the diagram showing the position of the connection leads and identify each one. Connect the leads to the binding posts or insert the unit in one of the sockets.

On Power types, clamp the unit to the heat sink to obtain good thermal contact using the brackets provided for this purpose. Check all connections.

TEST FOR SHORTED COLLECTOR:

Note the normal collector current listed and set the collector current switch accordingly. Index the Collector volts switch to the 6 volt position.

Be sure all warning lights are out, and the pilot is on. Check the maximum allowable collector voltage for the transistor to be sure it is at least six volts. Slowly rotate the collector control. The collector red warning light will first be illuminated and the collector voltmeter pointer will start up scale. Watch the collector current meter, and continue to increase the potential to 5 or 6 volts.

If the collector is free of shorts, the current meter will show little or no deflection. If this meter follows the voltmeter up scale with an appreciable deflection, then the collector is shorted to base or emitter, and the transistor is worthless. Put out the collector warning light by counter clockwise rotation of the Collector control, before disconnecting.

# COLLECTOR JUNCTION LEAKAGE CURRENT MEASUREMENTS

MEASURING $I_{CO}$:

From the listed information, find the maximum allowed $I_{CO}$ and the $V_{CB}$ at which it is rated. Index the Collector Volts switch to cover the $V_{CB}$ rating and the Configuration lever switch to Common Base. For example, a 2N111 shows a rated $I_{CO}$ maximum of 5 microamperes at a Collector voltage of 12 volts.

Rotate the Collector control to the correct value of $V_{CB}$ as read on the central meter. Shift the $I_{CO}$ lever switch to the 60 ma position. This sets up the correct measurement circuitry for $I_{CO}$ readings on the same meter that was reading collector volts. If, for example, a 2N174 is under test, the current reading can be taken on this range, since the $I_{CO}$ max. is listed as 10 ma for this type. Read current on the black arc numbered zero to 6. If no deflection is apparent on any transistor under test on the 60 ma range, shift the lever to the 6 ma position. If again no deflection is noted, or if the pointer reads **below** the 10% scale deflection, shift the lever to the 600 microampere position, and read the current in microamperes. An additional range of 60 microamperes is available by push button for readings down to 1 microampere. For a transistor in normal operating condition, the current reading should be **less than** the max. rating in the manufacturer's specification. Referring back to the 2N111, the reading should be less than 5 microamperes at 12 volts. For the 2N174 also previously mentioned, the reading should be less than 10 milliamperes at 60 volts. Do not disturb the collector control when taking current readings, since this was previously set for the correct collector potential for the $I_{CO}$ readings.

MEASURING $I_{CEO}$:

Refer to the listed information for the $V_{CE}$ and note the potential. Index the Configuration lever switch to the Common Emitter position.

Rotate the Collector control to bring the pointer of the Collector Voltmeter to the correct $V_{CE}$ reading. Shift the $I_{CO}$-$I_{CEO}$ lever switch to the 60 ma position. This sets up the correct circuitry for $I_{CEO}$ readings. Note the deflection on the center meter and read on the black arc marked zero to six, in terms of 60 ma full scale.

If the pointer does not deflect above the 10% mark, then this switch may be indexed to the 6 ma position, or lower ranges. In general, $I_{CEO}$ readings are higher than $I_{CO}$. For a transistor, the reading should be **less than** the manufacturer's listed maximum.

Index the lever switch back to the RET position, and lower the collector voltage to zero.

MEASURING $I_{CES}$:

Refer to the listed information or otherwise determine the $V_{CE}$ at which the measurement is to be made. Index the Configuration lever switch to the Common Emitter position. Be sure all warning lights are out.

Rotate the Input current switch to the Short position. Be sure the NPN-PNP switch is set correctly. Rotate the Collector control to bring the pointer of the Collector Voltmeter to the correct $V_{CES}$ reading. Shift the $I_{CO}$-$I_{CEO}$ lever switch to the 60 ma position. This sets up the correct circuitry for $I_{CES}$ readings. As recorded under $I_{CO}$ readings, shift the switch to a lower range and read the current on the black arc of the central meter marked zero to six, in terms of the corresponding lever switch position. For a normally operating transistor, the reading should be less than the manufacturer's listed maximum. Since the emitter and base are shorted this is also the value of $I_{CBS}$.

Index the lever switch back to the RET position, and lower the collector voltage to zero.

MEASURING $I_{CER}$:

Refer to the listed information or otherwise determine the $V_{CE}$ at which the measurement is to be made. Index the Configuration lever switch to the Common Emitter position. Be sure all warning lights are out. Rotate the Input current switch to the Open position. Select the resistance ($_R$) value desired for the $I_{CER}$ reading in accordance with the application of the transistor in its working circuit. A value of 10,000 ohms is quite common for this resistance or "$_R$", and may be used as a standard value if no further specific information is available. We will assume this value.

Be sure the NPN-PNP switch is set correctly. Clip a 10,000 ohm 1/4 or 1/2 watt resistor across the Emitter and Base binding posts. This can be made very convenient by making use of a General Radio type 274 or 274-MB connector. These binding posts have the 3/4" spacing that fits these connector plugs. Loosen the screws in the plug, insert the resistor leads and tighten them in place. This plug can then be inserted in the binding post tops even if the posts are in use for the transistor leads, or if the transistor under test is plugged into one of the sockets. The plug-in resistor thus available can be carried in the compartment of the analyzer as a useful accessory.

Rotate the Collector control to bring the pointer of the Collector Voltmeter to the correct $V_{CER}$. Shift the $I_{CO}$-$I_{CEO}$ lever switch to a suitable current range position and read the $I_{CER}$ on the black arc marked zero to six on the center meter.

MEASURING $I_{CBR}$:

This test is quite similar to the $I_{CER}$ measurement, except that the configuration switch is indexed to the Common Base position, thus placing the resistance in the emitter circuit. Refer to the listed information or otherwise determine the $I_{CB}$ at which the measurement is to be made. Index the configuration switch to the Common Base position. Be sure all warning lights are out. Index the Input current switch to the Open position. Select the resistance ($_R$) value desired for the $I_{CBR}$ readings in accordance with the application of the transistor in its working circuit.

Be sure the NPN-PNP switch is set correctly and clip the chosen resistance across the Emitter and Base binding posts. Rotate the Collector control to bring the pointer of the Collector Voltmeter to the correct $V_{CBR}$. Shift the $I_{CO}$-$I_{CEO}$ lever switch to a suitable current range position, and read the $I_{CBR}$ on the black arc marked zero to six on the center meter.

## EMITTER JUNCTION LEAKAGE CURRENT MEASUREMENTS

Any and all emitter or base input characteristics can be checked or studied with this analyzer other than those requiring high frequency apparatus, since independent full range continuous coverage of both voltage and current is available with multirange instruments. Care should be exercised in taking emitter or base readings where any appreciable potential is involved because the breakdown voltage of this part of any transistor is considerably lower than that of the collector circuit.

MEASURING $I_{EO}$ ($I_{EBO}$):

Refer to the transistor manufacturer's information for the maximum $V_{EBO}$ or $V_{EB}$. Index the configuration switch to Common Base. Be sure all warning lights are out. Index the Collector current switch to the Open position. Note the type of transistor, NPN or PNP. If the transistor under study is an NPN type, index the polarity switch to **PNP.** If the unit is a PNP type, index this switch to **NPN.**

If the $V_{EBO}$ is 1 volt or less, index the Input Volts switch to the 1.2 volt range. If higher, index this switch to the 12 volt range. Set the Input current switch on the 300 ua range. Connect the transistor to the binding posts or plug into one of the sockets. Slowly rotate the Input control increasing the emitter potential to the value to be used in the circuit under design, or to some value less than the $BV_{EBO}$. The Input microammeter will read the sum of the leakage current and the emitter voltmeter current. Leave the Input control at its present setting, and shift the Input Volts lever switch back to the RET. position. This will subtract the voltmeter current from the leakage current. Read $I_{EBO}$ in microamperes on the Input current meter. Return the Input control to zero extinguishing the warning light.

MEASURING $I_{EBS}$ OR $I_{ECS}$:

Where low impedance output circuits are involved, the input or emitter leakage current with the collector short circuited is of more interest than $I_{EBO}$, and will be of a higher magnitude. Proceed as under instructions for measuring $I_{EBO}$ in all respects except, index the Collector current switch to the "Short" position. Again index the polarity switch to PNP for the testing of NPN transistors, and to NPN for measurements on PNP types.

If $BV_{EB}$ is 1 volt or less, index the Input Volts switch to the 1.2 volt range. Set the Input current switch to the 300 ua range. Be sure the warning lights are out. Connect the transistor to the binding posts or plug into one of the sockets. Slowly rotate the Input control increasing the emitter potential to the value to be used in the circuit under design, or to some value **less than** the $BV_{EB}$. The Input microammeter will read the sum of the leakage current and the emitter voltmeter current. To read $I_{ECS}$, leave the Input control at its present setting, and shift the Input Volts lever switch back to the RET. position. This will subtract the voltmeter current from the leakage current. Read $I_{ECS}$ directly on the Input current meter. Return the Input control to zero extinguishing the warning light.

MEASURING $I_{EBR}$:

This is the input leakage current with the emitter reverse biased and a specific resistance, usually of fairly low value in the collector circuit. This measurement is of importance in circuit design particularly in class B amplifiers where the input characteristics must be known under definite load conditions.

Index the configuration switch to Common Base. Set the Collector current switch to the Open position. Index the polarity switch to PNP for the testing of NPN types, and to NPN for measurements on PNP types.

Index the Input Volts switch to the 1.2 volt range and the Input current switch to the 300 ua position. Be sure all warning lights are out. Connect a 1/4 or 1/2 watt resistor equal in value to the circuit requirement under design, between the Base and one of the collector posts. Plug in or connect the transistor. Rotate the Input control to apply the equivalent or required $V_{EB}$ always less than the $BV_{EB}$. The Input microammeter will read the sum of the leakage current and the emitter voltmeter current. Leave the Input control at its setting, and shift the Input Volts lever switch back to the RET. position. This will subtract the voltmeter current. Read $I_{EBR}$ directly on the Input current meter. This will fall somewhere between $I_{EO}$ and $I_{ECS}$.

## THE MEASUREMENT OF ALPHA, $h_{FB}$

Note the transistor type, NPN or PNP and set the lever switch accordingly. Index the Configuration switch to Common Base. Note the value of collector current $I_C$, at which the alpha rating is listed, and set the collector current switch to a suitable range for this current value. Set the input current switch to the same range. Be sure all warning lights are out.

Connect the transistor to the posts, or plug it into one of the sockets. Rotate the collector control slowly to a value of 5 or 6 volts as read on the collector voltmeter, unless some particular value is listed by the transistor manufacturer. Slowly rotate the input control watching the Input or Emitter Current. Bring this up to a value equal to the $I_O$ listing: The collector current should follow closely the emitter current. Divide the collector current by the emitter current for the value of alpha. For example, the 2N319 is listed as having a minimum value of alpha of .94 at a collector current of 1 ma. In this case adjust the Input or Emitter Current to 1 ma. The collector current will be somewhere between .94 and .995 ma if the transistor is within limits. Use the 1 ma range on both current meters for this type. Other current ranges may be used depending on the transistor rating, or conditions under which the measurement is to be made, but in all cases where alpha is to be measured, the same Emitter and Collector Current ranges should be indexed on the current meters. In other words, if the 10 ma range is used for Emitter Current, then the 10 ma range should also be used for Collector Current, since alpha or $h_F$ approaches unity. The Common Base configuration is always used for this measurement.

## THE MEASUREMENT OF DC BETA, $h_{FB}$

Note the transistor type, NPN or PNP and set the lever switch accordingly. Index the Configuration switch to Common Emitter. Note the value of Collector current $I_C$, at which the beta average or minimum value is listed and set the collector current switch to a suitable range for this current value. Set the input current switch to a lower current range determined by the beta value listed for the transistor under test. If the expected beta is between 10 and 100 as most often will be the case, index the input current switch to the position that calls for one tenth (1/10) of the collector current switch reading. For example, if the collector current of a particular power transistor is listed as 10 amperes, index the collector current switch to the 10 ampere position, and the input current switch to the 1 ampere position. In general, the one tenth to one ratio is the best combination. Where higher values of beta are expected, a lower input current range may be used. Since $h_{FE}$ is the ratio of collector current to input current, for best accuracy the lowest input range should be used that will deliver sufficient input current to drive the Collector current to its rated value.

For signal or low current transistors, note the normal operating collector voltage listed in the handbook or manufacturer's data sheet, and index the Collector Voltage switch to a suitable position for this potential. Be sure all three warning lights are out. Connect the transistor to the posts, or plug it into one of the sockets. Rotate the collector control to bring the center or collector voltmeter to the correct applied potential, using the right hand. With the left hand, slowly rotate the input control to apply base current .Both collector and input current meters will start up scale. Increase the input current until the collector current has reached the rated value, and correct the collector voltage, if necessary. Read the input current. Divide the Collector current by the input current for the measured value of $h_{FE}$. For example, a 2N1288 NPN switching transistor is shown in the handbook as having a minimum $h_{FE}$ of 50, measured at a collector current of 10 milliamperes. The $BV_{CE}$ is listed as 5 volts. To determine the dc beta of such a transistor, index the collector voltage switch to the six volt position and apply four volts to the collector (to stay under the 5 volt $BV_{CE}$ rating). With the collector current switch indexed to the 10 ma position and the input current switch indexed to the .3 ma position, apply the input current necessary to bring the pointer of the collector current meter to the 10 ma reading. Divide 10 by the input current value. For a good transistor, this value should be more than 50.

The effect or influence of collector voltage on the value of dc beta can be studied by varying the potential on the collector and noting the current readings and their ratio. Curves may be plotted holding one of the values constant, or $h_{FE}$ can be measured at any number of collector voltages, always holding the maximum $V_{CE}$ below the $BV_{CE}$ or breakdown potential.

In power or high current transistors, set the collector and input current switches as required and index the Collector Volts switch to the six volt position. Be sure all three warning lights are out. Clamp the transistor to the copper slab heat sink using one of the arrangements described in the section entitled "Connections to Transistors", page 5. Good contact with the heat sink must be maintained for both thermal transfer and electrical current flow. Check the NPN-PNP switch to be sure it is polarized correctly and set the Configuration switch to Common Emitter. Apply three volts to the collector using the right hand, and with the left slowly increase the input current. As the collector current increases, maintain the three volt collector potential by right hand rotation of the collector control. When rated collector current is flowing, read the input current and determine the current ratio for the $h_{FE}$ value.

The three volt collector potential is used here on the power types simply to limit the power dissipation in the collector supply. This same list could be made at 4 volts, or at 2 volts just as long as the collector voltage is above the saturation potential of the transistor. In general, three volts seems to be a generally acceptable figure. Where collector current above 10 amperes up to 20 amperes are involved, the operator should limit the time that the excess current over 10 amperes is applied to about thirty seconds. This avoids excessive temperature rise in the silicon rectifier supplying the collector current to the power transistor.

Again the influence of collector voltage on the value of dc beta can be explored by varying the collector voltage over a reasonable range and observing the collector to base current ratio.

## MEASURING AC BETA, $h_{fe}$

In general, DC beta measurements correlate closely with AC measurements on power transistors, and therefore AC readings on power types are of little or no importance and are difficult to undertake. However, on low current or signal types $h_{fe}$ tends to depart in value from $h_{FE}$ and ac readings take on real significance. This is particularly true of transistors with collector currents under 100 milliamperes. This Analyzer is equipped with a 1 Kilocycle sine wave measuring circuit for full scale beta readings of 300 and 600 on the center meter. These scale arcs and the controls that are peculiar to this function carry red markings.

To measure $h_{fe}$, set up the controls normally for measuring $h_{FE}$, the dc beta, making sure that the collector current switch is indexed to a current range of 100 milliamperes, 30, 10, 3 or 1. All higher dc current ranges are automatically excluded from ac beta measurements. Apply the correct collector voltage and current by rotating the collector and input controls in accordance with the procedure for measuring dc beta. Index the AC Beta rotary switch to the Set B position. This removes the central meter from the collector voltage circuit, connects it into the ac beta circuit and energizes the 1 kc signal source. Rotate the Set Beta control to bring the pointer of the meter to the Set AC Beta mark directly above the 500 reading on the top red scale arc. This standardizes the ac beta circuit. Index the AC Beta switch to the 600 or 300 position, and read 600 or 300 full scale on the corresponding red arc.

Another example of the flexibility of this Analyzer is apparent here. The input current, collector current, or collector voltage may be shifted and curves plotted of ac beta against any of these variables. Also the dc conditions for maximum value of ac beta may be explored.

## MEASURING SATURATION VOLTAGE AND RESISTANCE

The saturation voltage $V_{CE}$ Sat. is measured in the Common Emitter configuration, and is the minimum voltage that will produce full collector current with the transistor current saturated. Index the NPN-PNP switch correctly. Refer to the transistor manufacturer's specification sheet for the input and collector current ratings for saturation tests. Index the input and collector current switches correctly. Be sure all warning lights are out. Index the Collector Voltage switch to the 3 volt position. Rotate the input control to increase the input or base current to the rated value as read on the input meter. Holding the base current constant, slowly apply a small amount of collector voltage until the collector current comes up to the listed value. Read the Saturation Voltage, $V_{CE}$ Sat. on the central meter. For example, the type 2N457 transistor has a handbook listing of 5 amperes, collector current and 1 ampere base current, and under these conditions, the $V_{CE}$ Sat. should not be over 1 volt. In the example we will assume a reading of .64 volts.

The Saturation Resistance can readily be determined by dividing the $V_{CE}$ Sat. by $I_C$, the collector current. In the example above, $V_{CE}$ Sat./$I_C$=.64/5=.128 ohm for Rsat.

## MEASURING PUNCH THRU:

Punch Thru, sometimes referred to as "reach-thru", is a measure of the limit of emitter control with increasing collector potential. As the collector voltage $V_{CB}$, is increased, $V_{EB}$, the emitter to base will remain at a fixed low value in the millivolt region until the punch-thru voltage is reached. This effect of collector voltage on the emitter is caused by the spreading of the depletion layer into the emitter junction under the pressure of the increasing collector voltage. At the punch thru potential, the emitter to base voltage will suddenly start to increase linearly with increasing collector voltage, a signal that the punch-thru value has been exceeded. This is an important test since it will tell the operator the $V_{CB}$ that should not be exceeded if normal input control is to be expected.

To make this measurement, first be sure all warning lights are out. Connect the transistor and index the NPN-PNP switch correctly. Set the configuration switch to "Common Base" position. Examine the manufacturer's data to see if the punch-thru potential is listed. Since this is a limit value, there is no great reason to run all transistors to the limit value, and therefore, if the transistor is being used at 6 volts or 9 volts in a particular application, measurements up to or somewhat above these values will be entirely sufficient.

Set the Collector Volts switch to the 12 volt position. Rotate the Collector control clockwise until the center meter indicates full scale, or 12 volts. There is a small index line on the collector control knob, that normally lines up with the panel index line at the off position. This line will now be to the right of the shaft center, at about the 3 o'clock position. Note where it is for the twelve volt reading. Return the control to zero so that the collector warning light is extinguished. Index the Input Volts switch to the Punch-Thru position. Rotate the collector control slowly clockwise to apply the collector voltage. As this potential is applied, the center meter will read "emitter floating potential" at a sensitivity of 1.2 volts full scale. For most small or low power transistors, the floating potential will come up to forty or fifty millivolts, and will hold steady as the collector voltage is increased. If there is no punch-thru, or in other words the punch-thru potential is not reached when the collector control is rotated to the position noted before for 12 volts, then the meter reading will remain at approximately the original potential. In general, it should not rise over 10% scale or 120 millivolts during this test. If the punch-thru value is exceeded, the center meter will start up scale following the collector potential as the collector is rotated. When this occurs, the process should be repeated and the collector control stopped at the point where the meter reading or floating starts to increase. Then index the Input Volts switch back to the RET (return) position. The center meter will now read the Punch-Thru voltage of the transistor. It is assumed in making this test at 12 volts that the $BV_{CB}$ or $BV_{CE}$ potential listed for the transistor is greater than 12 volts. If not as is the case with the 2N523, this test must be run at 6 volts or lower. Under no conditions should a punch-thru test be made using collector potentials above the breakdown potential listing.

On power type transistors, the procedure is exactly the same. If the operator plans to use the transistor at 5 volts, a 6 volt punch-thru test is sufficient. If manufacturer's data is available, the test may be made at some other potential up to 12 volts $V_C$. In general the floating potential of the emitter or the power types may be somewhat higher than on signal units, but the test procedure is just the same.

The question may arise as to how to avoid avalanche breakdown in the transistor should the collector voltage be increased too rapidly when attempting to find punch-thru at collector potentials of 30 volts or above. When the Input Volts lever switch is indexed to the "Punch-Thru" position, a 390,000 ohm resistor is in series with the collector circuit, thus limiting the current and avoiding the avalanche breakdown.

With reasonable caution and following the procedure outlined above, punch-thru or reach-thru tests can be made without causing any damage to the transistors, and may be repeated when necessary. Occasionally a transistor will not exhibit a sharp break point, but will show increasing emitter floating potential at a fairly low Collector voltage, $V_C$. In such cases the punch-thru potential may be considered as the $V_C$ that is required to raise the floating potential to 120 millivolts on the Punch-Thru range. This is equivalent to 5 microamperes of leakage current in the emitter circuit, the greater part of which is caused by collector voltage influence. Other values may be published as new transistors are announced, or more definite information is available on presently available types, but as a general rule to follow where more specific information is not available, the 120 millivolt limit will suffice.

FLOATING POTENTIAL:

The emitter floating potential at any collector voltage level below the punch of reach-thru value may be measured on the central meter. If the voltage on an open-circuited emitter is observed while the collector to base voltage is increased, it will remain within 500 millivolts or less of the base voltage until the punch-thru potential is reached. This test can be made by connecting the transistor with the warning lights extinguished, and a suitable collector voltage range selected, generally under 12 volts. The collector control should be rotated to apply the correct $V_C$ and the index line position of the control noted. Return the collector voltage to zero and extinguish the collector warning light. Index the Input volts switch to the Punch-Thru position. Rotate the collector control back to the previously noted index line position, and read the floating potential on the central meter in terms of 1.2 volts full scale, or 1200 millivolts. The configuration switch must of course be in the Common Base position for these measurements.

## TETRODE TRANSISTORS:

Tetrode transistors, primarily used in RF amplifiers up to 200 megacycles, and as mixers and oscillators require 3 separate and independent power supplies for test measurements. This analyzer is so equipped to handle these types. Examples of these transistors are the 3N36 and 3N37.

Tetrodes are equipped with a second base connection to which an interbase potential is applied. This reduces the base spreading resistance, $R_B$ creating the equivalent effect of reduced cross section base region improving greatly the useful frequency of the unit. The so called "cross base bias" creates an electric field which compresses the active base region reducing the high frequency base resistance. Improvements of 10 to 1 are not uncommon in comparing the tetrode with a triode.

The tetrode or second base voltage supply is brought out to the red binding post on the copper heat sink, and is also available on the offset terminal of the round 4 pin socket. This is described in Figure 2 on page 5 under "Connections to Transistors". The voltage control is directly to the left of the Collector Volts switch, and is marked Tetrode Volts. This control is calibrated in volts from zero to 10.

Note the transistor type and index the NPN-PNP Switch accordingly. For alpha measurements, index the configuration switch to Common Base. Note the value of emitter current, and set both Input and Collector current switches to the same range. For the type 3N36 as an example, $I_E$ is listed as—1.5 ma so the current switches should both be set to the 3 ma range. Note the listed collector voltage and set the Collector Volts switch to the required range. In the case of the referenced transistor, this is 5 volts. Be sure all warning lights are out. Plug in or otherwise connect the transistor, and apply the correct collector potential.

Rotate the Input control to bring the emitter current to the correct value and note the collector current Alpha under these conditions is the collector current divided by the emitter current. Slowly rotate the Tetrode Volts control up to the listed value. For the 3N36 this is —2 volts. Note the automatic gain control effect on the alpha value.

This same test may be repeated under Common Emitter conditions. Extinguish all warning lights and index the tetrode volts to zero. Set the Input and Collector current switches for beta measurements. In the case of the 3N36, a suitable collector range is 10 ma and input range is 300 ua. Apply a collector potential again of 5 volts and then apply input current to bring the collector current to 5 ma as a suggested figure. Note the dc beta. Slowly apply tetrode volts and observe the effect on the collector current and the resultant $h_{FE}$. For the 3N36 this should be limited to 2 volts.

AC Beta or $h_{fe}$ may also be measured and the automatic gain control of the tetrode or second base observed. Return the tetrode volts to zero, switch to the Beta Set position and thence to the 300 range. Note the reading and then slowly increase the tetrode volts to the 2 volt potential.

Since all potentials are continuously variable and complete current and beta coverage is included in this Analyzer, curves showing one variable as a function of any of the others can be quickly and easily plotted. Efficient high frequency amplifiers with wide range coverage and smooth automatic gain control are quite practical with tetrode transistors.

# TESTING DIODES AND RECTIFIERS

Information:

Locate the type number of the diode in one of the data books available from manufacturers. Note the polarity or direction of Current flow as usually indicated by an arrow. Note also the rated average forward current, the PIV, or peak inverse voltage, and the leakage current maximum at the peak inverse voltage.

On the larger power types with forward average current ratings over 3 amperes, it may be advisable to clamp the rectifier to the heavy brass posts on the copper slab if full current is to be applied for any considerable length of time. On many rectifiers in this class, the mounting stud can be inserted through the hole in the post.

Note the average forward current, and set the collector current switch to handle this value. Index the configuration switch to Common Base position, and the Collector Volts switch to 3 volts. Be sure all of the special purpose switches are in the RET position, and all warning lights are out.

TESTING DIODES:

Index the left hand lever switch to NPN. Connect the diode between the heavy collector and the base binding posts, with direction of normal or forward current flow from collector to base terminals. In the NPN switch position the collector terminals are positive. Rotate the collector control slowly watching the collector ammeter. If the forward resistance of the diode is low, this meter will start up scale. Keep increasing the collector current up to the listed average value. The full-load Forward Voltage Drop will be indicated by the center meter. For many germanium and silicon diodes in normal operating condition, this will be in the order of .3 to .5 volt.

If there is no apparent current, the diode may be open, or it may be connected in the reverse direction. To determine which is the case, return the collector control to zero extinguishing the warning light. Shift the polarity switch to the PNP position. Slowly rotate the collector control. If the collector current meter deflects up scale and can be brought to the average rated full load current, then the diode was reverse connected. On the other hand, if no current deflection is noted on either the NPN or PNP positions, then the diode is open circuited.

After determining the full load forward voltage drop, return the collector control to zero, extinguishing the warning light. Shift the polarity switch from the NPN position where the forward current was applied to the PNP position. Note the rated PIV, peak inverse voltage and index the collector voltage switch to encompass this value. For example, a 1N1093 computer diode is listed with a reverse working voltage of 15 volts. In this case set the Collector Voltage switch to 30 volts. Rotate the collector control to bring the pointer of the collector voltmeter up to the listed potential. There should be no deflection on the collector current meter. In the example just mentioned this meter would be operating on the .1 ampere range since the average anode current for this diode is 50 ma. If the current meter deflects up scale, then the diode has broken down in the reverse direction, and can not be used at the normal reverse potential. Normally there will be no appreciable current indication, and the $I_{CO}$-$I_{CEO}$ switch may be shifted down through the current ranges until a readable deflection is noted. This is the leakage current at the reverse working voltage, sometimes referred to as the reverse current. For the 1N1093 this should be less than 75 ua at 15 volts. Some manufacturers list other reverse current values at potentials considerably below the peak inverse voltage or continuous reverse working voltage. For example, a second value of 25 ua at 5 volts is specified for this same diode. In all cases, the leakage or reverse current should be **less than** the manufacturer's maximum. Return the $I_{CO}$-$I_{CEO}$ switch to the RET position before proceeding with any other steps. Return the collector voltage to zero extinguishing the collector warning lamp.

Where peak inverse or reverse working potentials are encountered higher than 120 volts, measurements will have to be confined to this potential since this is the maximum available in the Analyzer. Under some low line voltage conditions, this may be closer to 110 V.

There are many types, kinds and varieties of diodes where the operator will be interested in additional tests. In some instances curve data may be valuable to pin point break points in the characteristics. By studying the description of the controls and following the test procedures already described he can work out for himself other procedures and measurements that will be of considerable value in the study of semiconductors.

TESTING RECTIFIERS:

Rectifiers are checked, measured, and tested in about the same manner as diodes, except that in general the working current values are higher. As mentioned in the second paragraph under "Information", heat sink considerations must be taken into account.

Proceed as under Diodes with the Collector current switch set to the correct position for the rated average anode current. Determine which is the cathode and which the anode of the rectifier. On heat sink types where the average anode current is of sufficient amplitude to require conduction cooling of the junction, fasten or clamp the stud or heat sink end to the large collector posts, or against the copper slab. If this happens to be the anode, index the polarity switch to the NPN position for forward conduction tests. On types where this is the cathode, index to the PNP position.

On silicon and germanium rectifiers, the collector voltage switch should be indexed to the 3 volt position for forward current tests. In general the threshold voltage is less than half a volt. This range provides the most accurate reading of full load forward voltage drop. Many of these rectifiers and diodes are listed by their manufacturers for minimum and maximum forward current at 1 volt. This can be measured quickly and easily using the 3 volt collector position. An example would be the 1N484B High Temperature Diode with a minimum forward current rating of 100 milliamperes at 1 volt.

SELENIUM RECTIFIERS:

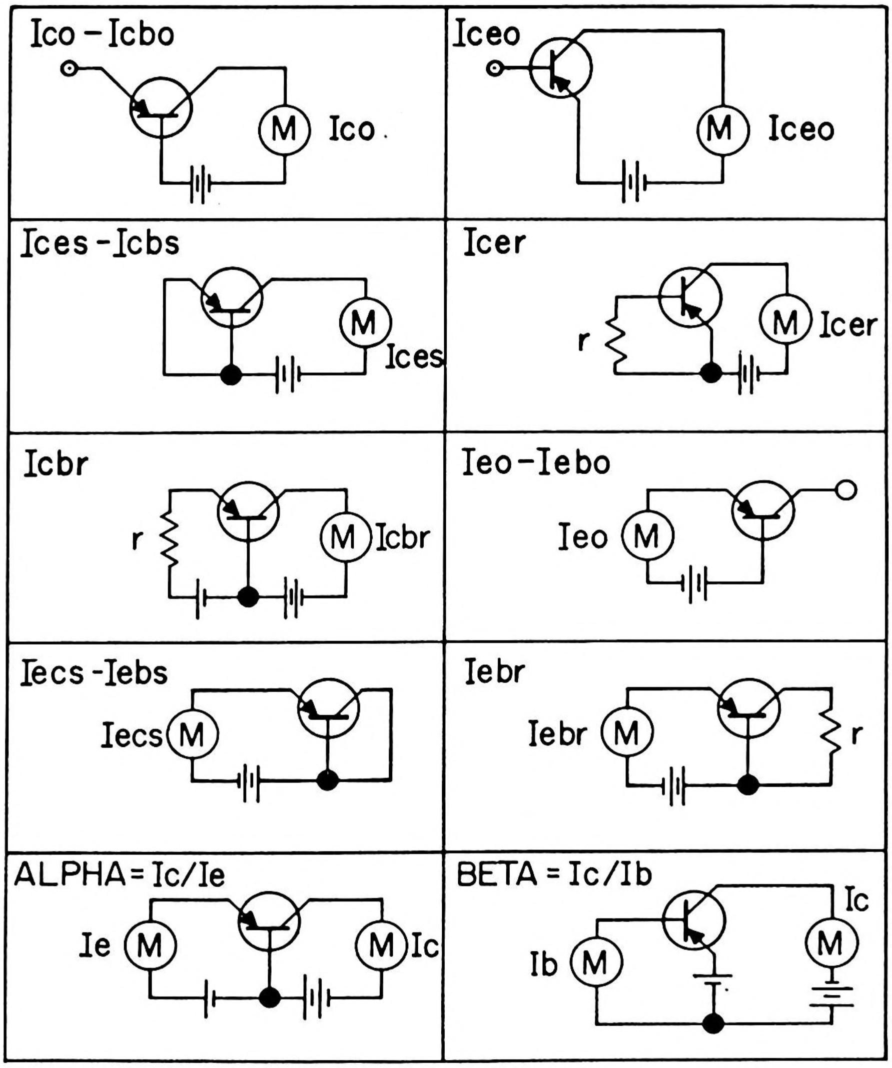
Selenium rectifiers do not have as low a forward resistance as germanium and silicon types. Where single discs are being tested or measured, the 3 volt range should still be adequate for full current forward voltage drop. Occasionally it may be necessary to use the 6 volt or the 12 volt range for collector potential. This is especially true of the rated 120 volt stacks which may have a full load forward voltage drop of 6 or 7 volts. In all other respects, the test procedure is the same as for the silicon types.

Copper oxide rectifiers are similar in forward characteristics to selenium. Care should be exercised in testing these units to be sure the peak inverse voltage is not exceeded when measuring reverse current.

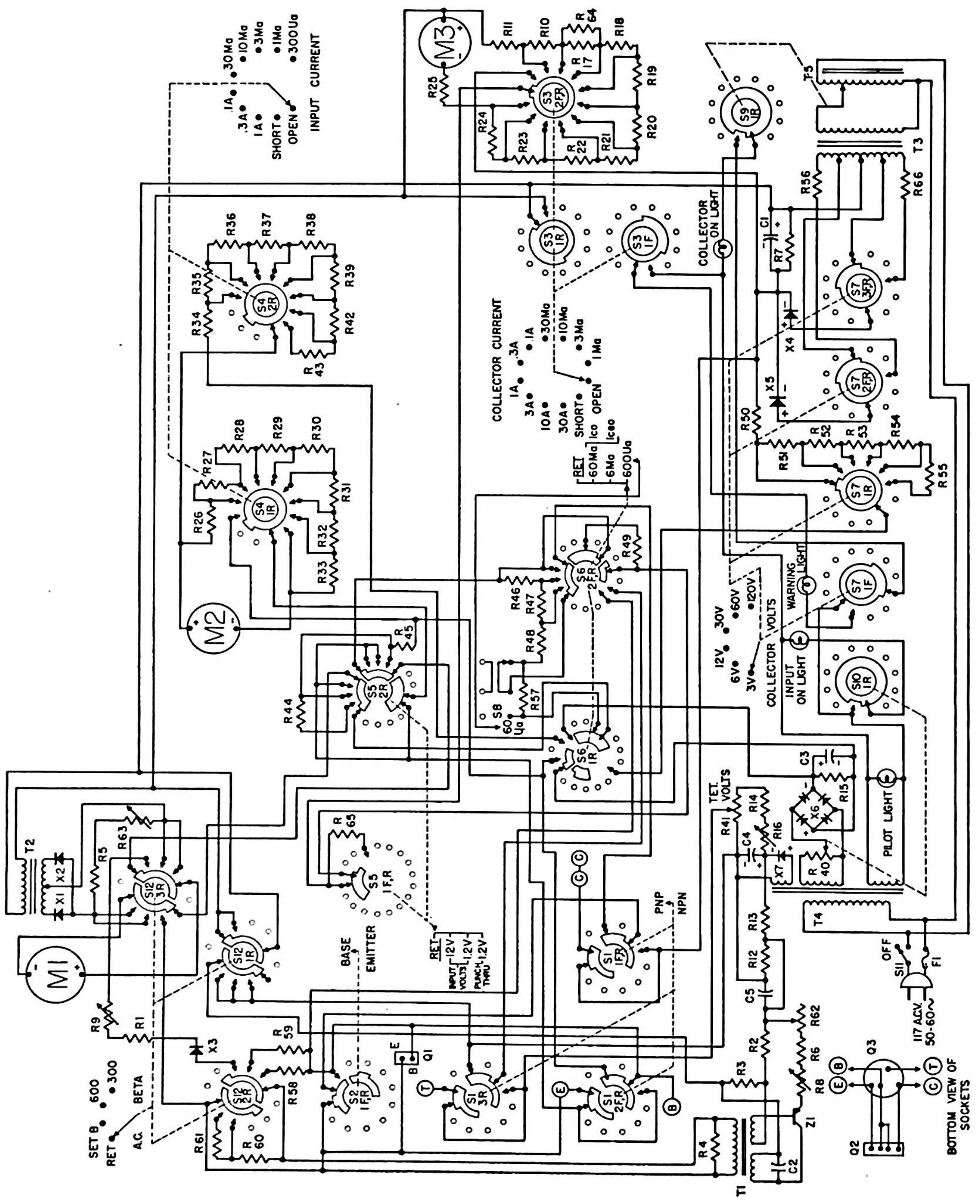
## PRECAUTION—WHEN TESTING ALL SEMI-CONDUCTORS

The $I_{CO}$-$I_{CEO}$ switch should be indexed into any current range for a limited interval only, and must be shifted back to the RET position as fast as a current reading can be taken. It is advisable to keep the fingers of the right hand on this switch all the time that it is in use.

## BASIC TRANSISTOR TEST CIRCUITS



# WIRING DIAGRAM, 3490



# REPLACEABLE PARTS LIST, 3490

| Ref. No. | Part No. | Req. | Part Name | Description |
|---|---|---|---|---|
| M1 | 52-1525 | 1 | Instrument | 420,200 Ua, Adjust to 500 ohms |
| M2 | 52-1526 | 1 | Instrument | 420, 50 Ua, Adjust to 2000 ohms |
| M3 | 52-1527 | 1 | Instrument | 420,200 Ua, Adjust to 500 ohms |
| S1 | 22A-379 | 1 | Switch | Lever, PNP-NPN |
| S2 | 22A-372 | 1 | Switch | Lever, Common Emitter-Common Base |
| S3 | 22A-419 | 1 | Switch | Collector Current |
| S4 | 22A-370 | 1 | Switch | Input Current |
| S5 | 22A-420 | 1 | Switch | Lever, Input Volts |
| S6 | 22A-421 | 1 | Switch | Lever, $I_{CO}$-$I_{CEO}$ |
| S7 | 22A-367 | 1 | Switch | Collector Volts |
| S8 | 22A-374 | 1 | Switch | Push Button |
| S9, 10 | 22A-375 | 2 | Switch | No Detent Single Circuit, Warning Lights |
| S11 | 22-116 | 1 | Switch | Toggle, On-Off |
| S12 | 22A-377 | 1 | Switch | A. C. Beta |
| | 22-412 | 1 | Switch Assembly | Collector Current, With Resistors |
| | 22-413 | 1 | Switch Assembly | Input Current, With Resistors |
| | 22-414 | 1 | Switch Assembly | Input Volts, With Resistors |
| | 22-415 | 1 | Switch Assembly | $I_{CO}$-$I_{CEO}$, with Resistors |
| | 22-416 | 1 | Switch Assembly | Collector Volts, With Resistors |
| | 22-417 | 1 | Switch Assembly | Push Button, With Resistors |
| | 22-418 | 1 | Switch Assembly | A. C. Beta, With Resistors |
| T1 | 23A-159 | 1 | Transformer | 1 KC Oscillator Coil |
| T2 | 23A-122 | 1 | Transformer | A. C. Beta |
| T3 | 23A-158 | 1 | Transformer | Collector Current, 100 W |
| T4 | 23A-115 | 1 | Transformer | Input Current, 25 Watt |
| T5 | 23A-124 | 1 | Transformer | Variable Powerstat |
| Q1 | 2455-232 | 1 | Socket | Power Transistor |
| Q2 | 2455-223 | 1 | Socket | 4 Pin Transistor, Rectangular, With Retainer Ring |
| Q3 | 2455-221 | 1 | Socket | 4 Pin Transistor, Round, With Retainer Ring |
| F1 | 3207-20 | 1 | Fuse | 3 Amp, 8 Ag |
| | 3207-19 | 1 | Fuse Holder | |
| L1, 2, 3, 4 | 67-99 | 4 | Lamps | Pilot, 6 Volt, (Bayonet Base) |
| X1, 2, 3 | 2250-47 | 3 | Diodes | 1N38A |
| X4, 5 | 2250-45 | 2 | Rectifier | 10 Amp Silicon |
| X6 | 2250-46 | 1 | Rectifier | Full Wave |
| X7 | 2250-40 | 1 | Rectifier | Half Wave |
| C1 | 43-238 | 1 | Capacitor | 200 MFD, 150 WVDC |
| C2 | 43-125 | 1 | Capacitor | .02 MFD, 600 WVDC, Ceramic Disc |
| C3 | 43-239 | 1 | Capacitor | 100 MFD, 25 WVDC |
| C4 | 43-240 | 1 | Capacitor | 20 MFD, 150 WVDC |
| C5 | 43-108 | 1 | Capacitor | .5 MFD, 200 WVDC |
| Z1 | 127-1 | 1 | Transistor | 2N591 |
| R1 | T-15-1447 | 1 | Resistor | 6.5K ohm ±1%, ½ Watt, Film Type |
| R2 | T-15-1179 | 1 | Resistor | 1500 ohm ±1%, ½ Watt, Film Type |
| R3 | T-15-1487 | 1 | Resistor | 47K ohm ±5%, ½ Watt, Composition |
| R4 | T-2601-½-1K | 1 | Resistor | 1K ohm ±10%, ½ Watt, Composition |
| R5 | T-15-2577 | 1 | Resistor | 2.2K ohm ±1%, ½ Watt, Film Type |
| R6 | T-15-3339 | 1 | Resistor | 700 ohm ±1%, ½ Watt, Film Type |
| R7 | T-15-2306 | 1 | Resistor | 5.6K ohm ±10%, 2 Watt, Composition |
| R8 | 16-129 | 1 | Resistor | 175 ohm Variable |
| R9, 63 | 16-122 | 2 | Resistor | 750 ohm Variable |
| R10 | 90-650 | 1 | Shunt Assem. | 10 Amp |
| R11 | 90-651 | 1 | Shunt Assem. | 30 Amp |
| R12 | T-15-1009 | 1 | Resistor | 5K ohm ±1%, ½ Watt, Film Type |
| R13 | 15-3343 | 1 | Resistor | 22K ohm ±1%, ½ Watt, Film Type |
| R14 | 15-2922 | 1 | Resistor | 15K ohm ±1%, ½ Watt, Film Type |
| R15 | T-2601-½-1000 | 1 | Resistor | 1K ohm ±10%, ½ Watt, Composition |
| R16 | T-16-90 | 1 | Resistor | 3500 ohm Variable |
| R17 & 64 | 15-3456 | 2 | Resistor | .14 ohm ±½%, Wirewound |
| R18 | 15-3215 | 1 | Resistor | .2 ohm ±½%, Wirewound |
| R19 & 27 | 15-3381 | 2 | Resistor | .7 ohm ±½%, Wirewound |
| R20 & 28 | 15-3043 | 2 | Resistor | 2 ohm ±½%, Wirewound |
| R21 & 29 | T-15-2058 | 2 | Resistor | 7 ohm ±½%, Wirewound |
| R22 & 30 | 15-3045 | 2 | Resistor | 20 ohm ±½%, Wirewound |
| R23 & 31 | 15-3363 | 2 | Resistor | 70 ohm ±½%, Wirewound |

## REPLACEABLE PARTS LIST, 3490

| Ref. No. | Part No. | Req. | Part Name | Description |
|---|---|---|---|---|
| R24 & 32 | T-15-3468 | 2 | Resistor | 200 ohm ±½%, ½ Watt, Film Type |
| R25 & 33 | 15-3339 | 2 | Resistor | 700 ohm ±½%, ½ Watt, Film Type |
| R26 | 15-3382 | 1 | Resistor | .3 ohm ±½%, Wirewound |
| R34 | 15-3409 | 1 | Resistor | 5 ohm ±5%, 5 Watt |
| R35 | T-15-3410 | 1 | Resistor | 15 ohm ±5%, 5 Watt |
| R36 | 15-3344 | 1 | Resistor | 60 ohm ±1%, 1 Watt, Film Type |
| R37 | 15-3336 | 1 | Resistor | 220 ohm ±5%, ½ Watt, Composition |
| R38 | T-2601-½-680 | 1 | Resistor | 680 ohm ±10%, ½ Watt, Composition |
| R39 | T-2601-½-2700 | 1 | Resistor | 2.7K ohm ±10%, ½ Watt, Composition |
| R40 | 16-135 | 1 | Rheostat | 25 ohm, 25 Watt |
| R41 | 16-102 | 1 | Rheostat | 2.5K ohm, ±10%, 2 Watt |
| R42 | 15-3337 | 1 | Resistor | 6.8K ohm ±10%, ½ Watt, Composition |
| R43 | T-2601-½-27K | 1 | Resistor | 27K ohm ±10%, ½ Watt, Composition |
| R44 | 15-3342 | 1 | Resistor | 216K ohm ±½%, ½ Watt, Film Type |
| R45 | 15-3343 | 1 | Resistor | 22K ohm ±½%, ½ Watt, Film Type |
| R46 | 15-2059 | 1 | Resistor | 10 ohm ±½%, ½ Watt, Film Type |
| R47 | 15-3340 | 1 | Resistor | 90 ohm ±½%, ½ Watt, Film Type |
| R48 | 15-3469 | 1 | Resistor | 900 ohm ±½%, ½ Watt, Film Type |
| R49 | T-2601-1-1K | 1 | Resistor | 1K ohm ±10%, 1 Watt, Composition |
| R50 | 15-3341 | 1 | Resistor | 58K ohm ±½%, ½ Watt, Film Type |
| R51 | T-15-3471 | 1 | Resistor | 60K ohm ±½%, ½ Watt, Film Type |
| R52 | T-15-3472 | 1 | Resistor | 120K ohm ±½%, ½ Watt, Film Type |
| R53 | T-15-3473 | 1 | Resistor | 360K ohm ±½%, ½ Watt, Film Type |
| R54 | T-15-3474 | 1 | Resistor | 600K ohm ±½%, ½ Watt, Film Type |
| R55 | T-15-2438 | 1 | Resistor | 1.2 Meg ohm ±1%, ½ Watt, Film Type |
| R56 & 66 | T-15-3411 | 2 | Resistor | 20 ohm ±5%, 1 Watt, Composition |
| R57 | T-15-3470 | 1 | Resistor | 9K ohm ±½%, ½ Watt, Film Type |
| R58 | T-15-2442 | 1 | Resistor | 100K ohm ±½%, ½ Watt, Film Type |
| R59 | T-15-1061 | 1 | Resistor | 200K ohm ±½%, ½ Watt, Film Type |
| R60 | 15-3085 | 1 | Resistor | 22K ohm ±5%, ½ Watt, Composition |
| R61 | 3995 | 1 | Resistor | 2K ohm ±5%, ½ Watt, Composition |
| R62 | T-16-117 | 1 | Resistor | 500 ohm ±20%, Variable |
| R65 | T-15-2347 | 1 | Resistor | 390K ohm ±10%, ½ Watt, Composition |
| | 79A-176 | 1 | Lead Assembly | |
| | 34-77 | 5 | Knobs | Pointer Type |
| | 34-76 | 2 | Knobs | Skirted |
| | 34-78 | 1 | Knob | Round |
| | T-34A-73 | 4 | Knob | Lever |
| | 2566-43 | 1 | Line Cord | 7 ft. long |
| | 10A-1642 | 1 | Case | Carrying |

## TRIPLETT WARRANTY AND CONDITIONS OF SALE

The Triplett Electrical Instrument Company warrants instruments manufactured by it to be free from defective material or factory workmanship and agrees to repair or replace such instruments which under normal use and service, disclose the defect to be the fault of our manufacturing. Our obligation under this warranty is limited to repairing or replacing any instrument or test equipment which proves to be defective, when returned to us transportation prepaid, within ninety (90) days from the date of original purchase.

This warranty does not apply to any of our products which have been repaired or altered by unauthorized persons or service stations in any way so as, in our judgment, to injure their stability or reliability or which have been subject to misuse, negligence, or accident, or which have had the serial number altered, effaced, or removed. Neither does this warranty apply to any of our products which have been connected, installed, or adjusted otherwise than in accordance with the instructions furnished by us. Accessories including all vacuum tubes and batteries not of our manufacture used with this product are not covered by this warranty.

The Triplett Electrical Instrument Company reserves the right to discontinue models at any time, or change specifications or design, without notice and without incurring any obligation.

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